GENERATION OF DUAL-WAVELENGTH EDFL BY USING S-M-S FIBER STRUCTURE AS A COMB FILTER BASED ON MACH–ZEHNDER INTERFEROMETER

JONATHAN A/L JOSE

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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JONATHAN A/L JOSE

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IR. DR. ANAS BIN ABDUL LATIFF
Pensyarah Kanan
Fakulti Kejuruteraan Elektronik Dan Kejuruteraan Komputer
Universiti Teknikal Malaysia Melaka (UTeM)
Hang Tuah Jaya
76100 Durian Tunggal, Melaka

Alamat Tetap: Taman Bukit Mutiara, Temiang, Seremban, Negeri Sembilan

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I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Electronic Engineering with Honours.

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DEDICATION

This speech is dedicated to my adoring parents, Jose A/L Skaria and Annamma A/P. Joseph, to my supervisor Ir. Dr. Anas Abdul Latiff, to my grateful family and all my friends and coworkers for their moral support, collaboration, encouragement, and understanding. I sincerely appreciate everything.

ABSTRACT

This experiment demonstrates a dual-wavelength fiber laser using S-M-S fiber structure. The ring laser cavity is integrated with a 2.4m Erbium Doped Fiber (EDFL) and a 6.6m single-mode fiber cavity. The developed fiber structure has a 22cm long multimode fiber with an insertion loss of 15 dB. The total dual wavelength of the ring laser cavity is 9.22m. Once the S-M-S fiber structure is integrated into the ring laser cavity, the slope efficiency drops from 11.6% to 0.21%. The stable peak wavelength at 1558nm and 1561nm are obtained within 39mW to 137mW pump power. Stable pulse train presence at a fundamental frequency of 24Mhz with a 33dB signal-to-noise ratio. The S-M-S structure has the potential to work as a comb filter for microwave source generator applications.

ABSTRAK

Kajian ini menunjukkan laser gentian dwi-panjang gelombang menggunakan struktur gentian S-M-S. Rongga laser cincin disepadukan dengan 2.4m Erbium Doped Fiber (EDFL), dan rongga gentian mod tunggal 6.6m. Struktur gentian yang dibangunkan mempunyai gentian sepanjang 22cm dengan kehilangan sisipan sebanyak 15dB. Jumlah dua panjang gelombang rongga laser cincin ialah 9.22m. Sebaik sahaja struktur gentian S-M-S disepadukan ke dalam rongga laser cincin, kecekapan cerun menurun daripada 11.6% kepada 0.21%. panjang gelombang puncak yang stabil pada 1558nm dan 1561nm diperolehi dalam 39mW hingga 137mW kuasa pam. Kehadiran masa denyut yang stabil pada frekuensi asas 24Mhz dengan nisbah isyarat-ke-bunyi 33dB. Struktur S-M-S mempunyai potensi untuk berfungsi sebagai penapis sikat untuk aplikasi penjana sumber gelombang mikro.

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LIST OF SYMBOLS AND ABBREVIATIONS

For examples:

WDM	:	Wavelength Division Multiplexed
MZI	:	Mach Zehnder Interferometer
OC	:	Optical Coupler
MMF	:	Multimode Fiber
SMF	:	Singlemode Fiber
S-M-S	:	Singlemode Fiber to Multimode Fiber to Singlemode Fiber
PC	:	Polarization Controller
DWFL	:	Dual Wavelength Fiber Laser
LD	:	Laser Diode
EDFL	:	Erbium Doped Fiber
EDFLL	:	Erbium Doped Fiber Laser
EDFLA	:	Erbium Doped Fiber Amplifier
ISO	:	Isolator
OSA	:	Optical Spectrum Analyzer
NA	:	Numerical Aperture
CW	:	Continuous Wave
CWFL	:	Continuous Wave Fiber Laser
W	:	Watt

MWFL	:	Multiple Wavelength Fiber Laser
DWDM	:	Dual Wavelength Division Multiplexed
MPA	:	Modal Propagation Analysis
BPM	:	Beam Propagation Method

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CHAPTER 1

INTRODUCTION

Fiber lasers, which utilize rare earth elements such as erbium and ytterbium as the active gain medium, have gained significant attention due to their potential applications in various fields. These lasers can produce multiple wavelengths, known as dual-wavelength operation, making them particularly useful in wavelength-division multiplexed (WDM) fiber communication systems, where multiple signals are transmitted simultaneously over a single fiber by using different wavelengths. In addition to WDM systems, dual-wavelength fiber lasers have potential applications in optical fiber sensing, instrument testing, and microwave photonic systems.

One method of achieving dual-wavelength operation in fiber lasers is using a Mach-Zehnder Interferometer (MZI) as a comb filter. The MZI comprises two optical

couplers (OCs) that divide light into two beams, which then interfere with each other in the second OC. The two beams experience different paths with a tunable phase shift, which allows for the creation of a comb filter effect. This filter is created by splicing a multimode fiber (MMF) section between two single-mode fibers (SMFs). By adjusting the states of a polarization controller (PC) appropriately, the laser can operate in stable single-, dual-, and three-wavelength lasing states.

The proposed method of using a comb filter based on an MZI in a fiber laser has the potential to offer several advantages, including low cost and compatibility with fiber optic systems. Additionally, the ability to adjust the phase shift allows for fine-tuning of the wavelengths produced by the laser, making it a valuable tool in various applications.

1.1 Problem Statement

In Dual-wavelength fiber lasers (DWFL), when the spacing between the neighbor wavelengths is less than the uniform linewidth of the gain fiber, it leads to intense mode competition and mode hopping. The homogeneous gain broadening of the medium causes this. To obtain stable DWFL, it is necessary to reduce the homogeneous broadening effect to prevent mode competition and mode hopping. One solution is to cool the erbium-doped fiber with liquid nitrogen, suppressing the homogeneous broadening effect [2]. However, this method has the disadvantage of being costly and having a complex and incompact structure.

An alternative solution is to use a Mach Zehnder interferometer (MZI) comb filter integrated into the erbium-doped fiber laser, this can suppress the multiwavelength operation and simultaneously keep the cost low, and the structure less complex and

more compact [3]. But using this method, the insertion loss of the comb filter may be higher due to the mode- mismatch when splicing two different types of fibers.

The use of a conventional all-fiber Mach Zehnder interferometer (MZI), which is composed of a 3dB optical fiber coupler, as a solution to suppress multiwavelength operation in dual-wavelength fiber lasers (DWFL) may have some disadvantages [3]. This approach is prone to temperature and environmental perturbations, even under laboratory conditions. This is because the large bulk of the all-fiber MZI can be affected by changes in the surrounding conditions, such as temperature variations and humidity. These perturbations can lead to unexpected shifts in the lasing wavelengths of the multiwavelength fiber laser, which can cause instability in the laser operation and impact performance [3]. This may limit the practicality of this approach, especially in specific applications where temperature and environmental stability are essential.

1.2 Objectives

1.2.1 To improve compact in fiber Mach Zehnder Interferometer comb filter formed by splicing a section of MMF between two SMFs.

To integrate a single mode fiber to multimode fiber to single mode fiber (S-M-S) Comb filter by splicing a section of MMF between two SMFs.

1.2.2 To achieve stable EDFL-based dual-wavelength lasing at room temperature by overcoming EDFL's homogeneous gain broadening effect to suppress the unstable mode competition.

Erbium-doped fiber (EDFL) is a homogenous broadening gain medium at room temperature, which results in severe wavelength competition and unstable lasing in

dual-wavelength Erbium-Doped Fiber Laser. To achieve a stable EDFL – based dual wavelength by using a Comb Filter based on Mach-Zehnder Interferometer to suppress the homogenous gain broadening effect.

1.3 Scope of work

A pump Laser Diode (LD), Wavelength Division Multiplexer (WDM), L-band Erbium Doped Fiber (EDFL), S-M-S Comb Filter, An Optical Coupler (OC), and Isolator (ISO) will be used in this project. Moreover, the structure of the fiber for splicing will be using two sections: Single Mode Fiber (All Fibers) and another choosing fiber, which will be using Multi Mode Fiber (MMF). The dual-wavelength fiber laser will be recorded in an Optical Spectrum Analyzer.